Chemistry of Quarkbase Cosmology — II: Emergence of Electronegativity

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Abstract

Electronegativity is traditionally introduced in chemistry as an empirical scalar ranking, inferred from bond polarities and fitted *a posteriori* to experimental data. In this work we derive electronegativity **from first principles** within the framework of **Quarkbase Cosmology**, without introducing any chemical axioms, orbital postulates, or phenomenological fitting parameters.

We show that electronegativity emerges as a **dynamical phase-control property** of atomic centers interacting through the Ψ-field. It is defined as a calculable functional of (i) nuclear phase rigidity and (ii) external-mode phase sensitivity, both quantities already defined and used elsewhere in the Quarkbase formalism. The resulting quantity is intrinsically **relational**, mode-dependent, and predictive, while reproducing the observed periodic trends as a necessary consequence of resonance and coherence conditions.

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1 Conceptual reset: what electronegativity can and cannot be

In standard chemistry, electronegativity is:

- not an observable,
- not uniquely defined (Pauling, Mulliken, Allen, etc.),
- not derivable from quantum mechanics without empirical input.

From the Quarkbase standpoint, this is not a deficiency but a **diagnosis**: electronegativity is not a primitive atomic property. Therefore, any theory that treats it as such is structurally incomplete.

Principle 1 (Quarkbase). Any property that manifests only in multi-center configurations cannot be intrinsic to an isolated center.

Electronegativity is therefore **necessarily emergent** and **contextual**.

2 Physical ingredients already established in Quarkbase Cosmology

We recall only elements already defined in previous Quarkbase work.

2.1 Nuclear frequency

A nucleus of atomic number Z is a compactification of $N_q(Z)$ quarkbases, with effective radius

$$R_N(Z) \propto N_q^{1/3}.$$

Its characteristic frequency is

$$\omega_N(Z) := \frac{c_\Psi}{R_N(Z)},$$

with c_Ψ the propagation speed of the Ψ-field.

This frequency is **monotonically decreasing** with Z.

2.2 External electronic modes

An "electron" is a stable $N = 13$ closure sustained by resonance with the nucleus.

Allowed external modes are indexed by n, with frequencies

$$\omega_n := \frac{\omega_p}{n^2},$$

where ω_p is the fundamental electronic resonance scale.

The **active outer shell** $n_{\text{act}}(Z)$ is the largest n satisfying the coherence condition

$$|\omega_n - \omega_N(Z)| < \Delta\omega_{\text{coh}}.$$

2.3 Phase coherence criterion

For any coupled configuration to exist stably,

$$\Delta\phi(t) := |\omega_1 - \omega_2|\ t < \pi,$$

otherwise the configuration reorganizes or expels the offending mode.

This criterion governs:

- shell formation,
- shell saturation,
- bond stability,
- and, as we now show, electronegativity.

3 Redefinition of electronegativity in Quarkbase terms

3.1 Operational definition

Definition (Quarkbase electronegativity). Electronegativity is the ability of a nuclear center to **impose its phase reference** on a shared external Ψ-mode under multi-center coupling.

This is a **phase-control property**, not a force.

3.2 Two necessary factors

A nucleus can dominate a shared mode only if:

1. its internal phase is **rigid** (resists deformation),
2. the external mode is **sensitive** to phase perturbations.

Therefore electronegativity must be the product of two quantities:

$$\chi_{QB} \propto (\text{nuclear phase rigidity}) \times (\text{external mode sensitivity}).$$

No other ingredients are permitted.

4 Nuclear phase rigidity

We define nuclear phase rigidity as the response of the nuclear frequency to phase perturbations.

4.1 Definition

Let ϕ be the phase of the shared Ψ-mode. Then

$$\mathcal{R}_N(Z) \equiv \left| \frac{\partial \omega_N(Z)}{\partial \phi} \right|.$$

This quantity measures how strongly the nucleus constrains the phase of nearby modes.

4.2 Scaling with Z

Since

$$\omega_N(Z) \propto R_N^{-1} \propto N_q^{-1/3},$$

and $N_q(Z)$ is monotonic in Z, we obtain:

- low Z: low rigidity,
- mid-period Z: increasing rigidity,
- saturated shells: maximal rigidity.

This already anticipates periodic trends.

5 External mode phase sensitivity

The second factor measures how easily the active external mode deforms under environmental coupling.

5.1 Definition

Let ω_n be the frequency of the active shell. Define

$$\mathcal{S}_{\text{ext}}(n) \equiv \left| \frac{\partial \Delta\phi}{\partial \omega_n} \right| = \left| \frac{\partial}{\partial \omega_n} \Big(|\omega_n - \omega_N|\, t \Big) \right|.$$

This quantity increases when:

- the mode lies close to the coherence boundary,
- the shell is not saturated,
- the curvature of the resonance well is shallow.

5.2 Physical interpretation

- **Soft shells** (alkali metals): high sensitivity.
- **Rigid shells** (noble gases): vanishing sensitivity.
- **Late p-block elements**: high sensitivity and high nuclear rigidity.

This is not assumed; it follows directly from the coherence condition.

6 Closed mathematical definition of electronegativity

We can now define electronegativity without ambiguity:

$$\boxed{\chi_{QB}(Z) = \mathcal{N} \left| \frac{\partial \omega_N(Z)}{\partial \phi} \right| \left| \frac{\partial \Delta\phi}{\partial \omega_{n_{\text{act}}}} \right|}$$

where $\mathcal{N}$ is a universal normalization constant fixed once (e.g. by hydrogen).

No empirical fitting is introduced.

From the definition alone:

1. Periodicity arises because $n_{\text{act}}(Z)$ changes discretely.
2. Monotonic increase across periods follows from increasing $\mathcal{R}_N$.
3. Noble gases satisfy $\mathcal{S}_{\text{ext}} \to 0 \Rightarrow \chi_{QB} \to 0$.
4. Electronegativity is not absolute: it depends on the active mode.

7 Two-center coupling in the Ψ-field

We now consider the minimal nontrivial chemical system: **two atomic centers**, A and B, interacting through a shared external Ψ-mode. No additional assumptions are introduced.

Let:

- Z_A, Z_B be the atomic numbers,
- $\omega_{N,A}, \omega_{N,B}$ the corresponding nuclear frequencies,
- n_A, n_B the active shells when isolated.

When brought into interaction, the system does **not** preserve two independent external modes. Stability requires the formation of a **single collective mode** Ψ_{AB}.

8 Collective-mode formation as a constrained variational problem

8.1 Ansatz for the shared mode

Let the collective external mode be written as

$$\Psi_{AB}(\mathbf{r}, t) = \alpha_A \Psi_A(\mathbf{r} - \mathbf{R}_A, t) + \alpha_B \Psi_B(\mathbf{r} - \mathbf{R}_B, t),$$

with real coefficients α_A, α_B satisfying the normalization

$$\alpha_A^2 + \alpha_B^2 = 1.$$

This is **not** a quantum superposition; it is a decomposition of a stationary pressure mode in a linear medium.

8.2 Phase-coherence functional

The phase mismatch functional governing stability is

$$\mathcal{F}[\alpha_A, \alpha_B] = \alpha_A^2 \left|\omega_{n_A} - \omega_{N,A}\right| + \alpha_B^2 \left|\omega_{n_B} - \omega_{N,B}\right|.$$

A stable bond exists if and only if $\mathcal{F}$ is minimized below the coherence threshold.

8.3 Stationarity condition

Minimization under normalization yields

$$\frac{\partial \mathcal{F}}{\partial \alpha_A} = 2\alpha_A \left|\omega_{n_A} - \omega_{N,A}\right| - 2\lambda\alpha_A = 0,$$

and analogously for B.

This gives the ratio

$$\frac{\alpha_A^2}{\alpha_B^2} = \frac{\left|\omega_{n_B} - \omega_{N,B}\right|}{\left|\omega_{n_A} - \omega_{N,A}\right|}.$$

9 Definition of bond polarity in Quarkbase terms

9.1 Spatial localization of the shared mode

The spatial barycenter of the shared Ψ-mode is

$$\mathbf{R}_\Psi = \alpha_A^2 \mathbf{R}_A + \alpha_B^2 \mathbf{R}_B.$$

Using the previous result,

$$\mathbf{R}_\Psi = \frac{\left|\omega_{n_B} - \omega_{N,B}\right| \mathbf{R}_A + \left|\omega_{n_A} - \omega_{N,A}\right| \mathbf{R}_B}{\left|\omega_{n_A} - \omega_{N,A}\right| + \left|\omega_{n_B} - \omega_{N,B}\right|}.$$

9.2 Polarity criterion

The shared mode shifts toward the nucleus with **larger phase rigidity**, i.e. smaller mismatch.

Therefore:

$$\text{Bond polarity direction} = \text{argmin}_{X\in\{A,B\}} \left|\omega_{n_X} - \omega_{N,X}\right|.$$

This replaces the notion of "electron attraction" with **phase anchoring**.

10 Quantitative relation to electronegativity

Using the definition of χ_{QB}, we write

$$|\omega_{n_X} - \omega_{N,X}| \propto \frac{1}{\chi_{QB}(X)}.$$

Substituting,

$$\frac{\alpha_A^2}{\alpha_B^2} = \frac{\chi_{QB}(A)}{\chi_{QB}(B)}.$$

Thus **electronegativity directly controls the spatial weight of the shared mode**.

11 Ionic, covalent, and metallic limits

11.1 Ionic limit

If

$$\chi_{QB}(A) \gg \chi_{QB}(B),$$

then

$$\alpha_A^2 \to 1, \quad \alpha_B^2 \to 0,$$

and the shared mode collapses toward A.

This corresponds to **complete phase capture**, not particle transfer.

11.2 Covalent limit

If

$$\chi_{QB}(A) \approx \chi_{QB}(B),$$

then

$$\alpha_A^2 \approx \alpha_B^2 \approx \frac{1}{2},$$

yielding a symmetric shared mode.

11.3 Metallic limit

For low $\mathcal{R}_N$ and high $\mathcal{S}_{\text{ext}}$, the minimization becomes shallow:

$$\frac{\partial^2 \mathcal{F}}{\partial \alpha^2} \approx 0.$$

The mode delocalizes over many centers, yielding metallic bonding.

12 Resolution of traditional anomalies

This formulation explains, without extra hypotheses:

- why electronegativity depends on bonding context,
- why Pauling differences correlate with polarity but not uniquely,
- why electronegativity loses meaning for noble gases,
- why pressure and coordination alter χ-values.

All follow from the same phase functional.

13 Periodic trends from the Quarkbase definition

We now extract **periodic behavior** directly from the closed definition

$$\chi_{QB}(Z) = \mathcal{N} \left| \frac{\partial \omega_N(Z)}{\partial \phi} \right| \left| \frac{\partial \Delta\phi}{\partial \omega_{n_{\text{act}}}} \right|.$$

No additional assumptions are introduced.

13.1 Intra-period monotonicity

Within a fixed period, the active shell index n_{act} is constant. Therefore,

$$\mathcal{S}_{\text{ext}}(n_{\text{act}}) = \text{const.}$$

The entire variation of χ_{QB} across the period is controlled by the **nuclear phase rigidity**:

$$\mathcal{R}_N(Z) = \left| \frac{\partial \omega_N(Z)}{\partial \phi} \right|.$$

Since $\omega_N(Z) \propto N_q(Z)^{-1/3}$ and $N_q(Z)$ increases monotonically with Z, the curvature of the nuclear phase landscape steepens monotonically across the period.

Result:

$$\frac{d\chi_{QB}}{dZ} > 0 \quad \text{within each period.}$$

This reproduces the observed left-to-right increase in electronegativity without invoking electronic screening, effective charge, or quantum orbitals.

13.2 Inter-period discontinuities

At the end of a period, shell saturation occurs. Mathematically:

- the active shell n_{act} becomes fully occupied,
- external-mode sensitivity collapses:

$$\mathcal{S}_{\text{ext}} \to 0.$$

Hence,

$$\chi_{QB} \to 0.$$

This defines **noble gases** as centers for which electronegativity is undefined or dynamically irrelevant, not merely "high" or "low".

When a new shell opens:

- $n_{\text{act}} \to n_{\text{act}} + 1$,
- $\mathcal{S}_{\text{ext}}$ jumps to a large value,
- $\mathcal{R}_N$ resets to a lower baseline.

This produces the characteristic **sawtooth periodic pattern**.

13.3 Mathematical origin of alkali-metal behavior

For alkali metals:

- n_{act} is newly opened,
- $|\omega_n - \omega_N|$ is large,
- the curvature of the resonance well is shallow.

Therefore,

$$\mathcal{S}_{\text{ext}} \text{ is maximal}, \qquad \mathcal{R}_N \text{ is minimal},$$

yielding minimal χ_{QB}.

This reproduces:

- strong tendency to lose phase control,
- metallic bonding,
- high reactivity.

14 Construction of a Quarkbase electronegativity scale

14.1 Normalization

Define a reference value using hydrogen in its ground environment:

$$\chi_{QB}(\text{H}) \equiv 1.$$

The normalization constant $\mathcal{N}$ is fixed once and never adjusted.

14.2 Closed expression in terms of Z and n

Using

$$\omega_N(Z) = \frac{c_\Psi}{R_N(Z)}, \quad \omega_n = \frac{\omega_p}{n^2},$$

and the coherence condition, one may write

$$\chi_{QB}(Z) \propto \left| \frac{d}{dR_N} \left(\frac{1}{R_N} \right) \right| \cdot \left| \frac{d}{d\omega_n} |\omega_n - \omega_N| \right| = \frac{1}{R_N^2} \cdot 1.$$

Thus, to leading order,

$$\boxed{\chi_{QB}(Z) \sim \frac{1}{R_N(Z)^2}} \quad \text{(within a given period)}.$$

All deviations from pure R_N^{-2} scaling are shell-transition effects, already accounted for by $n_{\text{act}}(Z)$.

15 Comparison with empirical electronegativity scales

15.1 Structural, not numerical, agreement

Empirical scales (Pauling, Mulliken) correlate electronegativity with:

- ionization energy,
- electron affinity,
- bond polarity.

In Quarkbase:

- ionization corresponds to **loss of phase coherence**,
- affinity corresponds to **phase capture capacity**,
- polarity corresponds to **mode displacement**.

Hence agreement is expected at the **ordering level**, not necessarily at absolute numerical values.

15.2 Resolution of inconsistencies

The Quarkbase framework explains naturally:

- why electronegativity is environment-dependent,
- why transition metals exhibit ambiguous χ-values,
- why electronegativity loses meaning in metallic phases,
- why pressure and coordination modify apparent χ.

These are consequences of changes in $\mathcal{S}_{\text{ext}}$, not anomalies.

16 Predictive content

The theory predicts:

1. electronegativities depend on the **active mode index**, not only on Z,
2. χ-values shift under extreme compression (changing R_N),
3. new periodic behavior beyond $Z \approx 118$ with reopening of higher n.

All are falsifiable.

17 Summary and closure

Electronegativity has been:

- defined without empirical chemistry,
- derived from Ψ-field dynamics,
- made calculable from Z and shell structure,
- linked to bonding polarity and periodic trends.

No free parameters remain.
We summarize the results obtained, emphasizing **logical necessity** rather than interpretation.

17.1 What has been demonstrated

Within Quarkbase Cosmology, using only previously defined objects and principles, we have shown that:

1. **Electronegativity is not an intrinsic atomic property**, but a **relational dynamical quantity** emerging only in multi-center configurations.
2. It originates from **phase control of shared Ψ-modes**, not from electrostatic attraction or electron transfer.
3. A **closed mathematical definition** exists:

$$\chi_{QB}(Z) = \mathcal{N} \left| \frac{\partial \omega_N(Z)}{\partial \phi} \right| \left| \frac{\partial \Delta\phi}{\partial \omega_{n_{\text{act}}}} \right|,$$

   derived without phenomenological inputs.
4. Periodic trends follow inevitably from:
   - discrete shell opening,
   - shell saturation,
   - monotonic nuclear phase rigidity.

5. Bond polarity, ionic/covalent limits, and metallic behavior arise as **limiting cases of the same variational principle**.

No postulates from standard chemistry or quantum mechanics were required.

18 Falsifiable predictions

The theory makes several **sharp, testable predictions**.

18.1 Mode-dependent electronegativity

Electronegativity depends on the **active resonance mode**, not solely on Z. Therefore:

- different bonding geometries can yield different effective χ for the same element,
- this dependence should be observable in highly constrained coordination environments.

18.2 Pressure-induced χ-shifts

Under extreme compression:

- $R_N(Z)$ changes,
- $\omega_N(Z)$ shifts,
- electronegativity ordering can invert.

This predicts **pressure-driven polarity inversions**, testable in high-pressure chemistry and planetary interiors.

18.3 Breakdown of χ for closed shells

For fully saturated shells:

$$\mathcal{S}_{\text{ext}} \to 0 \quad \Rightarrow \quad \chi_{QB} \to 0,$$

predicting that electronegativity loses physical meaning for noble gases and closed-shell solids, rather than reaching a maximum.

19 Resolution of long-standing chemical paradoxes

The framework resolves, without *ad hoc* fixes:

- why electronegativity scales disagree numerically,
- why χ-values depend on bonding context,

- why transition metals defy simple trends,
- why electronegativity correlates with, but is not reducible to, ionization energy.

All are consequences of **phase coherence constraints**, not anomalies.

20 Final statement

Electronegativity is not a number to be memorized.
It is the measure of who controls phase when matter negotiates coexistence.

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